MT ECCLES LAVA FLOW AND THE GUNDITJMARA CONNECTION: A LANDFORM FOR ALL SEASONS

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An archaeological investigation of the Tyrendarra Flow of Mt Eccles in temperate Southwest Victoria has demonstrated that the Indigenous occupants, the Gunditjmara, developed a socio-economic system based on the environmental characteristics of the lava flow. Basalt stones, the reliable rainfall, the shortfin eel *(Anguilla australis)* and the *Eucalyptus viminalis* woodland all contributed to the development of an aquaculture system covering 100 sq km. Manipulation of the landscape resulted in large-scale management of the wetland resources by the time of British colonisation. Resource specialisation including processing formed the basis of sedentary settlement.

Key words: Mt Eccles lava flow, Gunditjmara, Southwest Victoria, landscape archaeology, Shortfin eel, aquaculture, wetlands.

PIONEERING research in certain localities in Southwest Victoria, Australia, in the late 1970s led to hypotheses that, prior to the arrival of Europeans, Indigenous groups had achieved social cohesion and an economic system based on water control and eel trapping (Presland 1976, 1977;Coutts, Frank & Hughes 1978; Lourandos 1976, 1980a & b). New archaeological evidence supports the hypothesis that Gunditjmara settlement on the Mount Eccles lava flow in Southwest Victoria was based on the management and control of the Shortfin eel, *Anguilla australis* (Builth 2002b). This management regime incorporated modification of the landscape so as to ensure that spring and surface water were directed via channels into water bodies which were interconnected. The water bodies became the long-term habitat of the growing eels. The natural, modified or artificial channels that connected them ensured mature migrating eels access from the ponds through the laval landscape to the Darlots Creek and so to the ocean. Development of techniques for the trapping, processing and preservation of the migrating eels ultimately led to a Gunditjmara socio-economy analogous to so-called complex fisher-hunter-gatherer societies that existed elsewhere in the world (Builth 2002b).

The research was premised on human cultural potential being conditional upon the environment and human socio-economic potential being conditional on technological achievements (Hayden 1992). The landform known as the Tyrendarra Flow features environmental attributes that provided Gunditjmara with the basic means to develop their technology and economy.

Following Lourandos (1976:176), Presland (1976, 1977) and Coutts et al. (1978) in their interpretation of prehistoric Aboriginal land and resource use in this area of Southwest Victoria, and questioning the orthodox concept of the Australian Aboriginal hunter-gatherer economy based on an arid or semi-arid model of survival (Lourandos 1980a, 1980b), Lourandos' 1980b hypothesis was tested by this present study.

The archaeological finds support Lourandos (1980a & b) hypotheses and have initiated renewed enquiry into socio-cultural patterns in pre-contact Aboriginal Southwest Victoria leading to a re-interpretation of occupation patterns and the subsistence economy.

THE TYRENDARRA LAVA FLOW

The landform that constitutes the Mount Eccles lava flow is known geologically as "the Tyrendarra Flow". The Tyrendarra or Mount Eccles lava flow is one of the longest, most spectacular and distinct in Victoria (see Fig. 1). The Eccles landform has a geological signature known as "the stony rises" which is the weathered remains of the laval episodes. This geology consists of Pleistocene basalt that has produced red-brown, shallow, stony, gradational soils and supports woodland or open forest dominated by manna gum (*Eucalyptus viminalis*), blackwood (*Acacia melanoxylon*), and native cherry (*Exocarpus*

Fig. 1. Satellite image of Mt Eccles lava flow (LizardTech 2001).

cupressiformis). The physical characteristics can be steeply contorted and the boulder-strewn stony rises are prone to seasonal inundation (CONTEXT 1993:14). The Mount Eccles and Mount Napier (20km to the north east) eruptions, between them, "contain the most extensive and diverse collection of volcanic features in south-eastern Australia". The wetlands of the Tyrendarra Flow are of considerable significance in terms of examples of the effects and succession of volcanism on drainage (CONTEXT 1993:12,36).

Prior to the Mt Eccles' eruptions, the drainage of the gently south-sloping topography was via the ancestral valley and tributaries of Darlots River, at that time a "weakly incised" system to the west and north. The ensuing lava flows blocked and diverted the existing system causing the formation of lakes and swamps such as Whittlebury Swamp and the previously 30 km long Condah Swamp, also known as the Great Swamp in early ethnohistorical literature (Clark 1998-2000, Critchett 1990:54). Gorrie Lake and Swamp are situated on the eastern side of the lava flow, a result of the blocked Eumeralla River drainage. Homerton Swamp was formed by the blocking of the Fitzroy River (CONTEXT 1993:34.)

Mt Eccles lava flow is physically situated adjacent to four separate landforms which include the extensive Condah Swamp (now drained); the Heywood well-watered plains; Bessiebelle plains of swamps and woodlands; and Whittlebury Tertiary deposits (Williams 1988:33; CONTEXT 1993:14).

Mount Eccles consists of a main mound of scoria, 179 m a.s.l. with a flooded crater, Lake Surprise. The eruption points of the volcanic complex are situated along a 2 km crest - the product of numerous lava flows. There are lava channels associated with these features, and "a line of smaller spatter and cinder cones and craters" which extend to the southeast from the main crater (ASF 1995:46). The nature of this volcano is its "small number of eruption points which eject large volumes of basaltic lava from craters or elongated fissures", known as "effusive volcanicity" (CONTEXT 1993:28). It would have provided spectacular viewing. The lava from Mount Eccles "formed the great basaltic lake of the Stony Rises" (Boutakoff 1963:64). The 'lake' measures 16 km by 8 km (Rosengren in Context 1993:28-9). At its western end, an approximately 3 km wide flow travelled south along the valley of Darlots River, past Tyrendarra township, to the coast. The 50 km long flow ended at what is now Julia Reef, 15 km offshore in the Southern Ocean.

The terrain of the Eccles landform is dominated by lava surfaces that, at its northern beginning, stand up to 20 metres higher than the bordering wetlands. Apart from Mt Eccles, the highest terrain is only about 60 metres above sea level. Further south, nearer the coast, there is less variation in surface elevations. At Tyrendarra township to the south the lava-derived terrain is only 8 metres above sea level (see Fig. 1).

The age and frequency of the flows has been debated since the initial dating by Boutakoff (1963) of a Mount Eccles eruption between the end of the Pleistocene and before the sea advanced to its present level in the Holocene (Gill 1979, Ollier 1981). The most recent dating of the eruption is 27,000 years BP (Head et al. 1991) based on radiocarbon dating of sediment cores taken from the swamps of Condah and Whittlebury. Evidence from sediment cores supports the claim that Lake Condah did not exist prior to 8000 years BP (Head 1989, Head et al. 1991:303), and the adjacent Condah Swamp shows a transition from lake mud to peat occurring between 8000 and 9000 years BP. Prior to European drainage, Lake Condah was perennial although water levels would have seasonal variation. Condah Swamp could have had a greater seasonal variation.

Climate

The temperate climatic conditions are a product of the latitudinal position. The lava flow is situated between 38° 05' south and 38° 40' south, and extends from the coast inland for approximately 40km. The Mount Eccles lava flow receives high and regular rainfall. Today, the climate of this region is considered mild. However, there is a marked seasonality with a high variance in temperature, light and rainfall. The rainfall is seasonal, falling predominantly during autumn, winter and spring months as a product of westerly winds and cold fronts. Over the 50 km of the Tyrendarra Flow, the annual rainfall varies from 660-860 mm. Winters are cool to cold, mostly wet and on these plains near the ocean are prone to cold winds from the south-west. Average daily winter temperatures very between 5° and 13° C. Summers are warm to hot and much drier: average daily temperature ranges between 12° and 26° C, and with days over 38° C not unknown (CONTEXT 1993:12).

Natural Drainage

Running in a north to south direction, run-off from the Tyrendarra Flow drains into the southern ocean. Darlots Creek is the western boundary river and the Eumeralla drains the area to the east. Both rivers evolved into larger water bodies during times of high rainfall and run-off in some autumn, winter and spring months and were fed from natural drainage further to the north. In the case of the Darlots Creek, the catchment included the extensive Condah Swamp, at the northern limit of which is the present day township of Branxholme. The nature of the "open trap scoriae" at Lake Condah ensured a continual underground drainage which surfaced further south as Darlots Creek and sub-surface fed sinkholes and springs occurring south of Lake Condah (Ingram in Kenyon 1912:110). Outside of the Tyrendarra Flow, on all sides, were naturally extensive wetlands consisting of both permanent and seasonal swamps. Darlots Creek is currently listed as significant for both its aquatic and riparian qualities (Scott 1989:305; CONTEXT 1993).

The characteristics of the natural drainage from Condah Swamp and Lake Condah were critical environmental factors in the Gunditjmara wetland-use model presented in this paper.

Cultural Significance of Eruption

That the eruption of Mount Eccles was spectacular, there can be little doubt. The total formation of Mount Eccles itself happened rapidly, perhaps over a brief three month period (Ken Grimes, pers. comm. 1998).

Mount Eccles, known as *Budj Bim*, and its stones, has immense cultural significance for both the past Gunditjmara population and their present descendants. Their continued ties with the lava flow and the volcanic episode(s) that created it, illustrates the nexus between the geology and the culture.

To the Gunditjmara, and indeed many other Australian Aboriginal Language groups, *Budj Bim* is known to be part of a larger "Creation Ancestor" of enormous power, and therefore something to be highly respected (Keith & Theo Saunders, John Lovett, pers. comm..1998). Investigation into the *Dhauwurd wurrung* language name for Mount Eccles reveals something of its significance and meaning. *Puutch beem* means "High head", and is the word for the volcanic cone. *Tung att* means "teeth belonging to it", and is the word for the scoriae that occur at this site (Dawson 1881:lxxxii). The mounds of scoria can therefore be realised to be the teeth of the Ancestor.

There is little doubt that local Aboriginal groups had been witness to volcanic activity. There are local language words for both active and extinct volcanoes (Dawson 1881). The word for active volcano literally translates as "burning hill": *walpa kuulor* in *Chaap wuurong*, and *baawan kuulor* in *Kuurn kopan noot* dialect (Dawson 1881:xliv). In 1870 the Portland Guardian published a Gunditjmara local oral history that revealed witness of volcanic activity and the associated tsunami that was said to have drowned most of the people. The volcanoes of the Mount Vandyke group are named as appearing after a few days of volcanic activity. Mount Richmond was also erupting. It is predicted that "when Mount Gambier begins to burn and the earth to shake the tidal wave will come again" (Kerley 1981:144).

The esteem and respect given to the local volcanoes and their "stones" reflects their cultural significance. An understanding of this relationship between Gunditjmara and their volcanic landscape can be appreciated in the development of their culture and economy.

The proximity of parallel lava flows, from Mounts Eccles, Napier and Rouse to the east, made it easier for the Aborigines to retain occupation and defend their position against the British squatters in this area. It took much longer at this place for the Europeans to gain control and displace Gunditjmara. The defence of the Stones has become known as the Eumeralla Wars (Kiddle 1967, Boldrewood 1969, Christie 1979, Clark 1989, Cannon 1990; Critchett 1990; Builth 1996, 2002b). The reputation of the Stones, as a consequence and nature of the European invasion and Gunditjmara defence, has resulted in our present lack of knowledge regarding Gunditjmara socio-economy. Mt Eccles lava flow was not generally known to Europeans. Its reputation was such that it was avoided (Bonwick 1857). However, there were exceptions to the total isolation of the stones from ethnographic records. There were some brief documented visits to its eastern edge at Lake Gorrie in the early 1840s by Robinson (Clarke 1998), Westgarth (1846:8) Sievwright and Fyans (quoted in Gerritsen 2000:17), and later surveyor Ingram (Worsnop 1897:105-6).

Ecological Context

The formation of numerous wetlands with associated species within a matrix of weathered basalt and varying densities of *Eucalyptus viminalis* woodlands and grassland (CONTEXT 1993) has provided a biologically-productive environment. It provided high resource potential for human exploitation.

The cool, wet winters, combined with the clay-rich soils and impeded drainage of the basalt flows, results in a large area of this region being saturated if not swampy (Williams 1988). Lourandos (1980:30) has described almost the entire Gunditjmara territory as an area of "water excess", being the consequence of perennial streams, lakes and swamps. This situation ensured almost continual run-off which had evolved specific ecosystems centred on wetland and river species. The resulting high productivity, with seasonal species differentiation, makes this an attractive environment for exploitation of natural resources (Dinnin and van de Noort 1999). The environmental conditions provided unique opportunities for the local Indigenous people, the Gunditjmara.

Flora

A plethora of plant resources was available in wetlands and the woodlands of the stony rises. Plants as staple food sources in the southeastern part of this continent consisted in the main of bulbs, roots and tubers. In addition there were some fruits and berries, leaves and shoots, seeds, nectar and pith. As a group, plant foods peaked in the months from spring to early summer and were in lower quantities during autumn and winter (Lourandos 1980b:34). However, it is in the autumn and winter months that the floral and faunal resources of the wetlands are at their most productive. Gott (1985, pers. comm. 1996,) suggested that the environment had a direct effect on Indigenous economies: "the vegetation of the tribal area was central to such ecological differences, because it determined above all the daily food supply, whether of plant or, frequently, of animal kind." Her studies have illustrated how reliance on seeds, being a seasonal resource, prevents permanent settlement; whereas occupation of cooler, wetter environments rich in perennial root plants supports a more sedentary occupation (Gott 1982; Clarke 1985). It has been estimated that 50% - 80% of an Indigenous family's food in these environments of Southwest Victoria was obtained by women, and the staple vegetable diet consisted of tubers, corms, rhizomes and roots obtained by systematic and predictable foraging (Gott 1982, 1983, 1985; Gott and Conran 1991:1-3, Zola and Gott 1992:6). This almost certainly led to a high regeneration for the species concerned (Kirkpatrick 1994).

One of the most widespread vegetable food resources in Victoria, was the Murnong or Yam Daisy (*Microseris lanceolata*). Underground tubers were baked in different regional styles of oven (Kenyon 1928:141, Coutts 1981, Gott 1982, Gott and Conran 1991:11-25).

There are many species of tubers, roots, rhizomes, and bulbs growing on the stony rises that were used as the staple food resource, rich in starch and other carbohydrates (Gott 1982; Williams 1988:29). Many of these consisted of different species of lilies and orchids. Several wetland species can be termed "ecologically flexible" due to their occurrence as permanently submerged aquatic, amphibious, and dryland plants depending upon the seasonal conditions. The tolerance of these species to wet, dry and damp conditions is significant for humans as these characteristics allow sustainability of sedentary human groups (Builth 2002b). This difference between dryland and wetland tubers illustrates the significance of wetlands as a permanent habitat for indigenous foraging groups.

Fauna

The Mount Eccles lava flow, with its many environmental zones, supports a wide variety of fauna including now rare mammals, reptiles, birds and fish. The large variety of faunal species that was present on the lava flow prior to European settlement served as a rich resource base available to Gunditjmara throughout the seasonal cycles. As a consequence of European farming practices the stony rises are habitat to many species that have now become rare, including the Tiger Quoll and some species of bats (Belcher 2003). Past studies have under-reported amphibians, reptiles and bats (CONTEXT 1993:70). The close proximity of the riparian habitat of Darlots Creek makes the wetlands particularly species-rich and biologically productive in comparison to other more simple categories of lake or swamp. One hundred and five indigenous birds species have been recorded, including six now threatened species. All but one of these is classified as a wetland bird (CONTEXT 1993:70). However, the key wetland species that inhabited Southwest Victoria, it can be argued, was the Shortfin eel, *Anguilla australis* Richardson (Builth 1996, 2002b).

SHORTFIN EELS AND GUNDITJMARA

The Shortfin eel was the most consequential Gunditjmara food resource. It is a reliable provider of high quality protein and lipids. It is seasonally predictable and abundant and, as it is highly territorial, its availability is assured throughout the year. This knowledge was utilised efficiently and to great effect by Gunditjmara. Technology was developed to ensure its efficient exploitation and processing. The staples of tubers combined with eel satisfied basic nutritional requirements for many Indigenous groups in western Victoria (Lourandos 1980a). The eel's capacity for preservation further meant it was ripe for long-distance trading (Builth 2002b).

The Shortfin eel is one of four species of eel endemic to Australian coastal catchments. It is a temperate species but this includes a territorial range extending from southeast Queensland to Victoria, Tasmania and the Murray River in South Australia (Gooley et al. 1999).

Eels are harvested by humans in two different ways: large numbers are caught in creeks or channels over a short period of time by the use of fixed weirs and net fish traps during their annual migration back to the spawning grounds in the Pacific Ocean, or smaller numbers can be caught in wetlands or lakes etc on a more regular basis throughout the year using spears, lines or nets. These methods have been used the world over by many different Indigenous groups throughout the Holocene (Moriarty 1978, Pedersen et al. 1997, Builth 2002b). Eels have always offered a high return for energy expended due to their nutritional composition and high oil content. This is also the situation today on many continents, with eels remaining a desirable and prized catch. There is an unsatisfied export market for Shortfin eels from Australia presently. Australia is currently conducting feasibility studies and researching the potential for more intensive eel aquaculture (Gooley et al. 1999).

The environment, resulting from specific geological, biological and climatic relationships, plays a major role in the subsequent human relationships that evolved with it (Dinnin & van de Noort 1999). In Australia, as elsewhere in the world, wetlands were "the richest of all food environments" (Zola & Gott 1992:10). In Southwest Victoria and in particular on the Tyrendarra Flow, the landscape exhibits a high ecological integrity. The Manna Gum woodland and forest is juxtaposed with wetland depressions, sinkholes and abutting swamps bordered by Darlots and Eumeralla Rivers. The result of this combination is a heterogeneous distribution of environmental zones with unique faunal and floral assemblages. The latitudinal and bio-physical conditions are a favourable destination for the Shortfin eel. Williams, while investigating an archaeological site on the eastern side of the Tyrendarra Flow, claimed that:

> Lakes and swamps contain higher numbers of eels relative to other habitats because they act as a nutrient sink. The largest numbers of eels are found in shallow lakes and swamps, such as those common in the study area, since these habitats trap a greater amount of energy in the form of sunlight (Beumer in Williams 1988:28).

The ethnographic and ethnohistorical records tell of an economy heavily dependent on exploiting eels, and the observations of the large-scale regional utilisation of fishtraps and eel weirs (Kenyon 1928; Lourandos 1980a &b; Clark 2000-2002; Builth 2002b). It is the potential of natural ecosystems to contribute to human economic systems (with subsequent social implications) that in the past has facilitated cultural complexity or the development of human societies (Hayden 1992, Coles et al. 1999, Builth in press).

Archaeological Investigation on Mt Eccles Lava Flow

In addition to eel exploitation, documented descriptions by explorers and squatters are testament to the many types and examples of Indigenous housing existing prior to European contact (Builth 2002b, Clark 2000). (The identification and interpretation of archaeological remains on the Mount Eccles lava flow supports the reliability of this archival material – see also Wesson 1981). The archaeological infrastructure underlies the hypothesis that, at the time of the British occupation of Southwest Victoria, a settlement existed on the Mount Eccles lava flow that was testament to a Gunditjmara socio-economy that was based upon wetland management and eel exploitation.

> The periodic return of Aborigines to regular camp sites, and their construction of durable huts, stone weirs and extensive channels indicate a situation of greater peace and security than has been envisaged by [some historians such as] Blainey (Christie 1979:19-20).

Environmental manipulation by Indigenous Australians for the purpose of trapping fish has been described before in the literature (Worsnop 1897; Robinson in Kenyon 1928; Smyth 1972a:201; Happ 1977; Coutts et al 1978; van Waarden and Simmons 1992; Clarke 1998; Lourandos (eg 1980a). However, the extent of this manipulation, it is suggested, has not been fully appreciated. Analysis of archaeological remains at a landscape level is viewed as the most appropriate means to investigate past economies and settlement patterns (Lourandos 1980b). Certainly evidence of large-scale environmental manipulation could be overlooked using a small-scale archaeological excavation. (It is highly likely that this may have occurred during Australian archaeological studies [Lourandos 1980b:353; Head 2000]). The patterns investigated during the study included ecological relationships on the Mt Eccles landform. By using suitable investigative methods it is possible to identify economic activities and ascertain their social repercussions on Gunditjmara society (Builth 2002a).

It can be demonstrated, using a Geographical Information System (GIS) to simulate past water flows through the now-drained landscape, that a coordinated system of land management had been put in place by Gunditjmara to take advantage of the ecological traits of the Shortfin eel. It is argued that more orthodox archaeological methods such as excavation are inappropriate for investigating Gunditjmara socio-economy on this landscape (Aldenderfer & Maschner 1996; Builth 2002a; Gillings, Mattingly & van Dalen, 1999). Without the use of GIS to interpret cultural footprints on this landscape, the study could not confidently be undertaken. Using GIS to reconstruct past water flows has determined the function of archaeological remains associated with hydrological activities (see van Waarden & Wilson, 1994). The results of this landscape analysis support a claim for eel aquaculture being the primary activity across this landform.

The GIS analysis of a Digital Elevation Model (DEM) of the southern study area near Tyrendarra reveals that water flow was maintained through channels so that migrating eels could make their way downstream to the ocean and be trapped in a series of weirs. Channel modification, including construction by excavation through the lava flow, had been carried out to ensure control of the migration routes – both upstream from the ocean and downstream back to the spawning grounds. In addition, the natural wetlandscape had been artificially extended spatially and temporally by the construction of dams to retain water channelled in from the river upstream.

Consisting of a series of wetlands interconnected by channels with additional side channels from the boundary river, the whole system was designed to raise and maintain wetland water levels, grow eels, and efficiently trap them in the eel traps built behind the weirs and throughout the channels when they eventually made their way back to the ocean to spawn some 7 to 20 years later. Via the simulated waterflows using GIS, it can be demonstrated that elvers were brought from the boundary river into a system of channels, pens and wetlands. During this time they were available for catching with spears, the "bob" method, or in individual traps (Builth 2002b). The weirs are also positioned to double-up as traps during the mature eel migration runs by incorporating the arrabines or woven traps into their structure. Other remains downstream from the weirs are also interpreted as eel trap remains.

Eels are highly territorial (Moriarty 1978). They also have definite requirements regarding a preferred location in which to live and grow before their return to the ocean (McKinnon & Gooley 1998; Gooley et al. 1999). Gunditjmara understood these requirements and provided a suitable habitat for them. At the same time these conditions also fulfilled the environmental needs of other wetland resources and nutritional staples, such as the bulbs and tubers, in addition to plant materials for organic-based artefacts (Gott 1982, 1993, Gott & Conran 1991, Zola & Gott 1990). Wetlands were the most exploited local environment for this Indigenous nation (Godfrey 1994:110). The result of the economic endeavour was a sustainable socio-economy based on a potentially sedentary settlement through wetland management. As a consequence of constructing and maintaining these systems, valuable resources were available throughout all seasons and over many years. In cases of extreme drought the eels could enter a state of torpor until the waters returned (Moriarty 1978).

Analysis of Study Areas

Both the north and south of the lava flow were the subject of archaeological investigations. However, the two study areas did not feature the same environmental characteristics and consequently a suite of archaeological features exist that are predicated on the particular environmental conditions. These reflect the environmental changes that occur over the length of the flow as a result of the volcanicity (Rosengren in Clarke 1991; CONTEXT 1993). A methodology was designed that established the basis of site identification (Builth 2002a, 2002b:Ch.3). Fig. 2 shows the separate study sites on the lava flow in relation to the Darlots Creek.

Within the northern area there are numerous small (<20 m dia.) natural water-filled sinkholes within a mainly flat basalt-strewn plain incised with major channels paralleling the Darlots Creek to the west. These channels enter and leave a series of swamps. The northern study area also features woodland with large individual trees of Stringy bark or Messmate (*Eucalyptus obliqua)*, Manna gums *(Eucalyptus viminalis)*, Swamp gums (*Eucalyptus ovata)* and Blackwood wattle (*Acacia melanoxylon)*. A survey of 59 mature *E. viminalis* and *E. ovata* trees confirmed that a high percentage had been culturally modified (Builth 2002a, 2002b:152-176). Attributes were collected and analysed in order to form a hypothesis regarding their cultural utilisation.

The 40 ha south study area consisted of large areas of potential waterbodies joined by relatively short channels, plus side channels that connected the boundary river, Darlots Creek, directly with the waterbodies.

Both sites, as representative of the whole lava flow, feature areas of well-drained land in the form of terraces or flat higher ground that enable the construction of dwellings and what has been identified as storage areas (Builth 1996, 2000). A schematic cross-section of the edge of the stony rise, modeled on that existing to the southeast of Lake Condah, is shown in Fig. 3. It represents a weathered "finger" of the flow, typical of the features that occur adjacent to swamps and lowlands of the Mt Eccles landform. Close examination of the flow reveals the weathering process and offers the means to discriminate between natural and cultural stone "circles".

A number of distance analysis functions were carried out to identify any spatial correlation between structures, and between the structures, natural features and the simulated water flow (Aronoff 1989). Proximity analysis using GIS was used in order to better understand spatial relationships between the archaeology and the landscape. In this way the two separate landscape analyses on different parts of the

Fig. 2. Positions of Northern and Southern study areas within lava flow (map: D.James).

2. survey of topography, including boundary river

A pattern or framework was formed from features that interconnected for resource allocation and resource optimisation. In order to decipher how the variables relate spatially, they were analysed with reference to:

1. each other.
2. their components.
3. other clusters.
4. other structures.
5. topographical features, including water bodies.

This involved investigating:

1. mean distances between features.
2. relationship of cultural stone circles to a simulated water level.
3. patterns of proximity.
4. clustering of stone circles.
5. water flows: their levels and contiguity.

It was anticipated that use of GIS, including spatial analysis, will show:

1. a map of the main data base.
2. patterns in the data base.
3. the function of, and clear relationships between, archaeological features.
4. the basis of the socio-economy on the Tyrendarra Flow prior to European arrival, given a specified set of characteristics from the data base.

In the northern area the DEM was used to analyse the proximity of a main channel featuring eel trapping complexes adjacent to trees and dwellings (see Figures 4 and 5). Following initial proximity analysis, the focus in the north study area became a study of culturally modified trees (CMTs) and eventually biomolecular analysis. The north study site has also been used to undertake specific analyses of stones, their positions and sizes, and the origins and formation of stone features (Builth 2002a). (Detailed measurements of the stones used in the construction of dwellings and storage caches have not previously been undertaken for archaeological studies on this landform; this may have contributed to presumptions of features being of natural rather than cultural origin [Clarke 1991, 1994].)

In the south study area, the European draining of the land and the subsequent loss of the large trees show a different environment with which to understand and interpret past land-use by Gunditjmara (Builth 2000). Previous large wetland areas still show

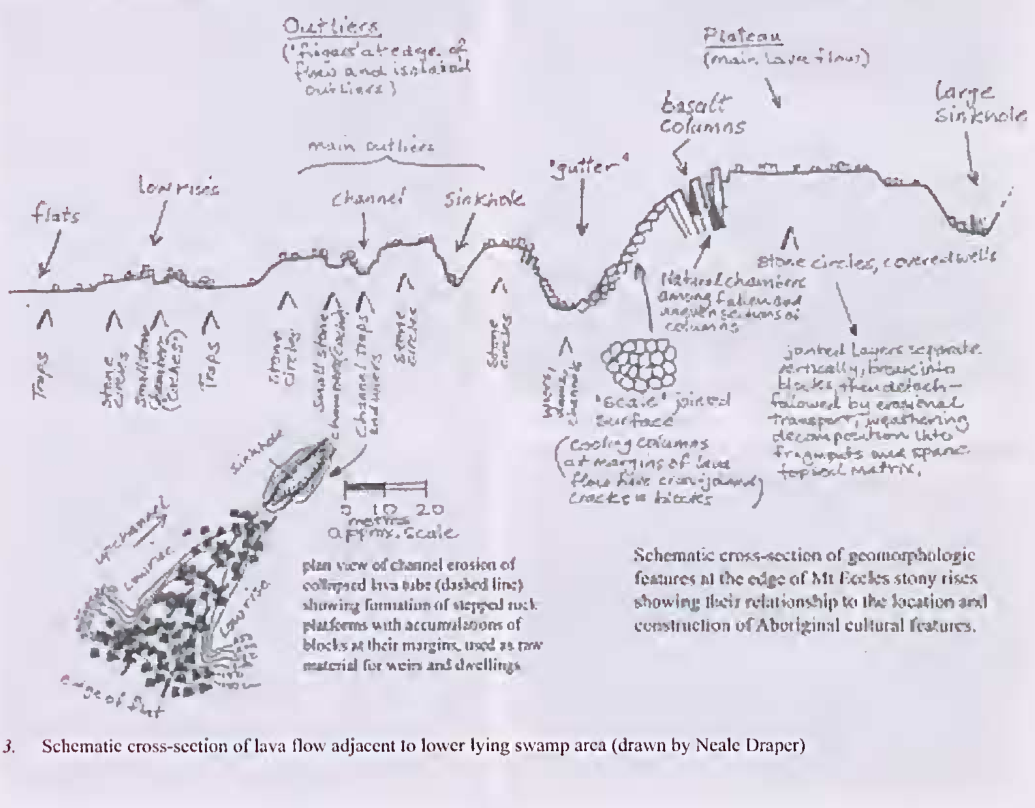

Fig. 3. Schematic cross-section of lava flow adjacent to lower lying swamp area (drawn by Neale Draper)

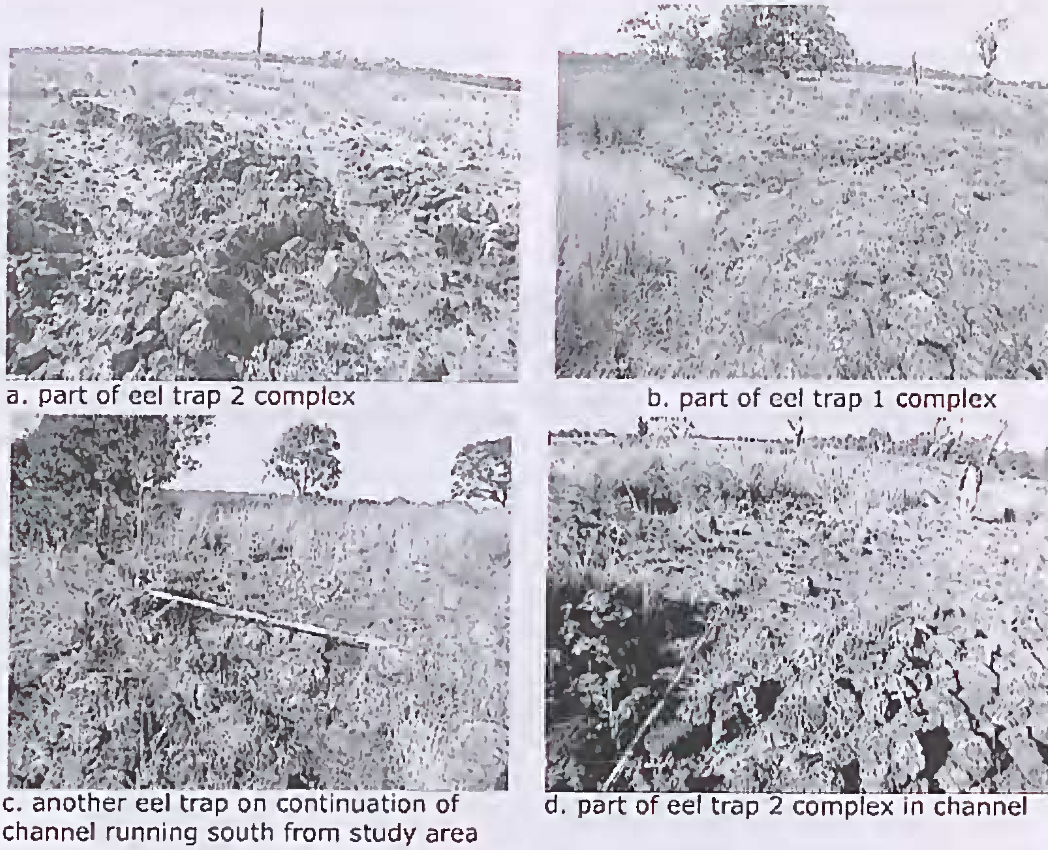

Fig. 4. Eel traps in Northern study area on one channel (photos H.Builth)

landform; this may have contributed to presumptions of features being of natural rather than cultural origin [Clarke 1991, 1994].)

In the south study area, the European draining of the land and the subsequent loss of the large trees show a different environment with which to understand and interpret past land-use by Gunditjmara (Builth 2000). Previous large wetland areas still show evidence of having been dammed. There is a series of excavated parallel channels from the boundary river heading west to the dammed wetlands. A central main channel joins these wetlands. The presence of archaeological remains that have been interpreted as former dwellings and storage caches are in proximity to the wetlands. The GIS map showing the relationship of the archaeology and natural features can be seen in Figures 6 and 7.

Water bodies and Eel traps

Across approximately 100 sq kms of the Mt Eccles lava flow, an extensive area of water bodies feature the remains of dams constructed to maintain a perennial wetland regime. These water bodies are interconnected by channels that contained a series of traps along their length, commencing immediately downstream of the dam. Culturally constructed inlet channels from Darlots Creek to the dammed water bodies have been demonstrated as the means of bringing in elvers from the migration corridor into permanent wetland habitat (Builth 2000). It is argued that the archaeological remains of inlet channels, the dammed water bodies, and the traps, in combination demonstrate the previous existence of large-scale eel aquaculture (Builth 2000, Builth 2002b:211-274).

Directly upstream from the eel trap complex in

Fig. 5. Remains of dwellings in the Northern study area (photos H.Builth).

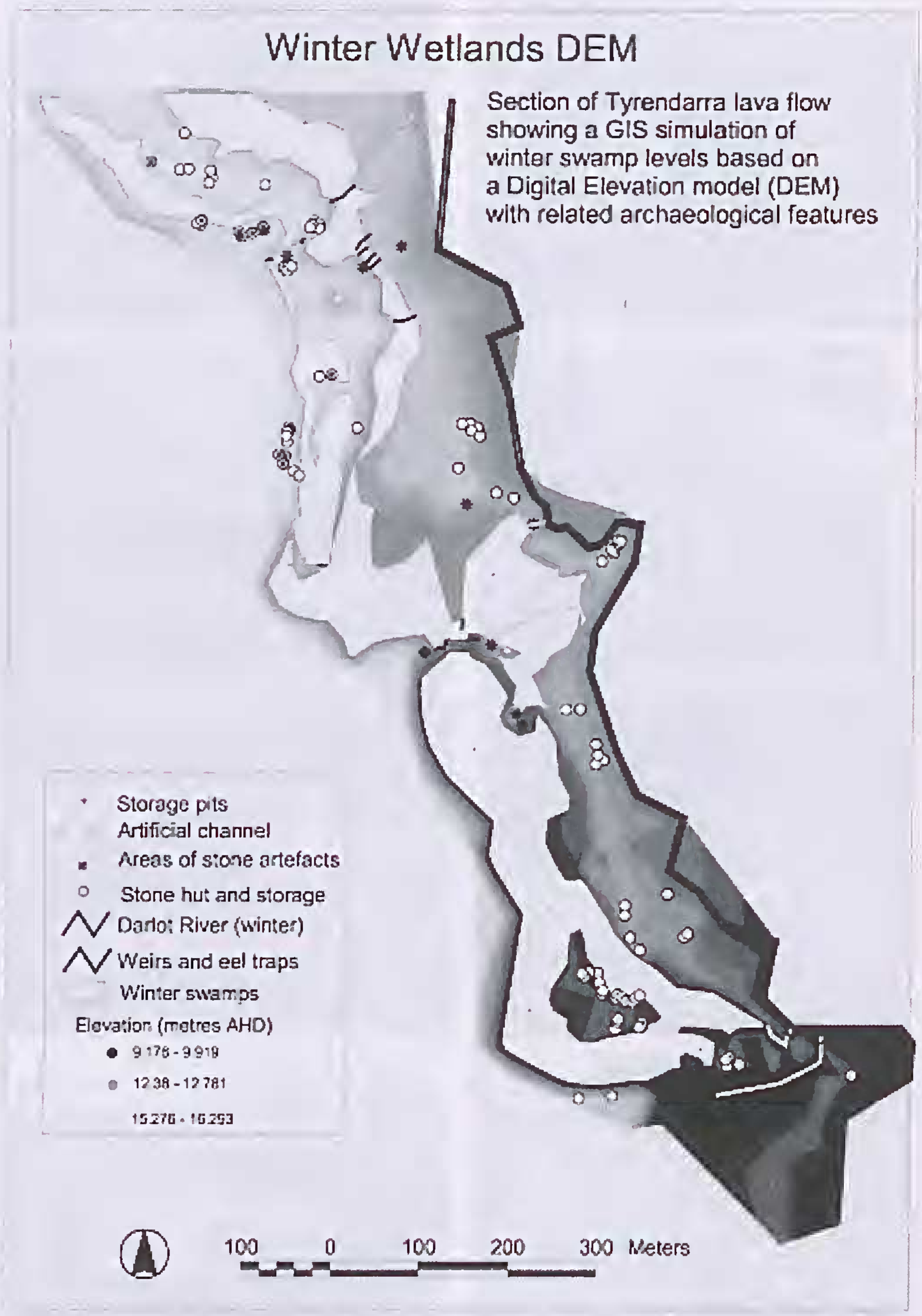

Fig. 6. GIS simulated winter wetlands for Southern study area

the northern study area it is suggested the channel has been formed into an area that has been used to hold or "grow" eels. All along the sides of this wider section of the channel are rocks that are black from being water-logged, and that have been positioned there (see Fig. 8). It is likely that these held in place woven lattice type "walls" to contain the eels, which, given the nature of the surrounding land, could have moved out to other wet areas.

In the north study area, immediately upstream of the eel trap complexes, it can be observed that water is held in the ponds by an edge or lip having been excavated for this purpose. It is suggested this was achieved by the application of fire and water to crack and excavate broken rock. (This method, it has been suggested, may have been used to quarry greenstone at Mt William in Victoria [McBryde 1984]).

In the south study area water is held in the wetlands by damming. The traps are also placed immediately downstream of the dams which demonstrate that seasonal flows are factored in by the height of the dam (see Fig. 7). When the autumn rains come and the migrating eels are on the move south to the ocean, they go over the dams and through the traps, but during summer and/or drier times water is held back to enable the wetlands to thrive and eels to grow.

The southern study area is topographically suited to the construction of a series of large water bodies that were able to contain, and grow to maturity, the highly territorial Shortfin eel, and so provide the daily requirements of eel protein and wetland vegetable staples. Adjacent well-drained terraces proved to be ideal residential locations. Activity areas and dwellings are closely related to the presence, seasonal or otherwise, of water bodies - be they channels or wetlands. Hundreds of dwelling and storage remains have been observed in such proximities. Fig. 6 shows the juxtaposition of dwellings, storage, water bodies with weirs and channels in the south study area.

The existence of a continuous series of large "growing ponds" or wetlands in the southern area, and the consequent availability of the resource on a daily basis, could mean there is less demand in this area for preserving eels and more for it as a residential site.

The north study area shows that even the smallest area of water was captured and used for the growing of eels. Each such area had a trap downstream that came into play when the eels were migrating and that also may have doubled as a weir or barrage to keep the water in during drier times. However, water flow through channels during heavy rain and migrations was always assured.

Culturally Modified Trees

After examination of trees in spatial association with archaeological features it was considered possible that a large number of hollow trees had been culturally modified. It was observed that the incidence of modified *Eucalyptus viminalis* and *Eucalyptus ovata* occurred in spatial association with both the dwelling/storage sites and the eel traps at this area, and that this pattern continued outside of the study area on the remainder of the lava flow. It was hypothesised that hollow trees, initially formed by the natural process of termite activity, were utilised to satisfy cultural requirements that enabled sedentary settlement on the lava flow.

Attributes were collected in an attempt to quantify the tree modification, and to ascertain the function of the trees (Builth 2002a:152-176). It was observed that entrances were made into hollow trees by cutting through the outer layer of bark, and/or burning

Fig. 7: GIS map of weirs/dams in relation to channels and elevation in south of Southern study area.

Fig. 8: Channel upstream from eel trap complex flanked by lines of rocks to contain growing eels (photo H.Builth).

through the remaining outer layers. Very often burnt scars were still visible. Examination of some of the culturally modified tree bases showed a bimodal differentiation by either containing broken pieces of basalt within an ash and charcoal matrix, or else charcoal and a "greasy" sediment.

The proximity analysis and statistical analysis of tree attributes led to the hypothesis that many trees had been culturally modified and were performing two significant separate functions within the settlement economy. These were

1. to carry out domestic family baking on the stones
2. to smoke, and therefore preserve, migrating eels caught in adjacent traps.

It can be further hypothesised that these two socio-cultural activities were gender divided with the women taking control of the family cooking and the men dealing with the resource processing.

The first function evolved from the necessity to carry out overnight domestic baking of the staple vegetable roots and tubers as it is not possible to construct a baking oven on the lava flow. It is hypothesised that the basalt pieces functioned as oven heat stones. Modifying mature eucalyptus trees to serve as ovens in order to carry out domestic baking was convenient and also innovative. It is of significance that the existence of sediment contained within the base of tree hollows is one of the few terrestrial situations on this landform where stratigraphy exists. Thus it is able to feature as a baking oven by containing the heat stones and tubers or roots that have been put in a woven bag within a matrix of sediment to bake overnight, as is the custom (Dawson 1881:103; Gott 1982).

Recognition of these trees as culturally modified infrastructure with which to perform domestic functions has not been recognised previously by archaeologists. (This may in some way explain the conclusions of Clarke (1994) that the hypotheses of villages and permanent occupation on the lava flow was an archaeological construction.)

The second function of the trees in close proximity to the traps as smoking chambers for processing the large annual eel catch explains how it was possible to deal with the large eel numbers and ensure their preservation (see Figure 9). Preserving the sea-

Fig. 9: *E. viminalis* used in GC/MS analysis (photo H.Builth).

sonally abundant resource would logically facilitate its storage or trade and the regional ethnographic record for eel trading contributed to the hypothesis that CMTs performed this function (Robinson in Kenyon 1928:141; Morgan 1852:55-56). A method was sought to test for this (Fankhauser 2001). A positive result would prove crucial in redefining Gunditjmara settlement and establishing a new socio-economic model.

GC/MS Analysis

The fact that only modified trees are found within 20 metres of the eel traps suggests that these trees were an integral part of the aquaculture system and especially high activity eel processing areas in close proximity to the traps. During the relatively short annual autumn migration, large numbers of eels would be making their way to the ocean along the channels and high density processing, including the smoking and preserving stage, would be expected to occur adjacent to the traps thus maximising energy efficiency. There is a need to preserve the eels for storage or trade, or else risk wasting them or the opportunity their migration offered.

The short-finned species, *Anguilla australis* from Victoria showed more than 55% greater fat content while migrating as compared to feeding eels (Sumner et al. 1984). The changes that occur in lipid content in growing eels (Sumner & Hopkirk 1976; Sumner et al. 1984) is significant when considering that their highest fat content is reached just prior to the annual autumnal migrations of mature individuals. Feeding eels had a fat content of 12.6% and migrating eels 19.0%. This is therefore the optimum time for their exploitation from a consideration of caloric content and the generic Indigenous desire for high energy-giving fats and oils. Capture and preservation of eels, therefore, at this particular point in their long lives would justify the great investment of human energy required for their harvesting and processing.

A decision was made to test for lipids, including fatty acids, as a means of ascertaining if the culturally modified trees (CMTs) had been used for the purpose as stated in 2, above. Identification of fatty acids emanating from the shortfin eel, *Anguilla sp.*, in samples taken from within the base of certain hollow trees, would provide strong evidence for this. Figure 9 shows one of the trees which contained sediment that was tested with GC/MS. Sediment from four trees have been tested.

Following GC/MS analysis, biomolecular evidence was obtained that supports eel processing having taken place (Builth 2002b:177-210). All sediment samples were positive and contained the crucial fatty acids that enabled them to be identified.

Although the residues extracted from sediments found in hollow trees were degraded there were still unsaturated fatty acids, 16:1, 18:1, 18:2, 20:4, and 20:5, present. Arachidonic acid, 20:4, and timnodonic acid, 20:5, are commonly found in aquatic animals in relatively high levels and are rare in plants. Given the large amounts of long chain fatty acids, an aquatic source is most likely. In addition, cholesterol was present which indicates an animal source and this coupled with the presence of cetyl alcohol gives an aquatic animal source for the origin of the residues. A relatively high amount of 18:2 fatty acid points to a freshwater fish source. Given the context of the samples the most likely source of the residues is eel processing (Fankhauser 2001:11).

Archaeological evidence of resource preservation supports a revised model of Gunditjmara settlement on the lava flow (Testart 1982).

DISCUSSION

The archaeological features, that were an integral part of the aquaculture system, occur in association with each other and particular natural features. The combination of the environmental requirements to carry out the eel aquaculture, processing and residential settlement – that is, stones, water and trees, were present in abundance on the same landform that the eels migrated to and through. The topographical and biological contrasts and similarities between the two study sites are reflected in the types of cultural usage that Gunditjmara had undertaken in these areas. Each shows how different environmental attributes have contributed to the particular Indigenous land usage.

The present interpretation of the archaeology of the Mt Eccles lava flow can be compared to the hydraulic manipulation documented by Lourandos near Toolondo to the north east of the present study area (1980b). Remains of weirs elsewhere in the region have been documented (Builth 2002b:56-69, 92-98). Certainly this technology existed throughout the region but the extent of wetlandscape manipulation in Southwest Victoria is not known.

The positive identification of eel lipids supports the hypothesis for smoking and therefore preserving and storing this species. It also supports the former identification of storage caches adjacent to dwelling remains (Builth 1996:114-122, Builth 2002b:211-258). This is the first time that trees have been identified as performing a vital role in Aboriginal socio-economic activities with significant ramifications for cultural development.

The topography, the channels – with their instream series of growing ponds and weirs for trapping, plus the presence of large mature trees, are the environmental evidence for the suitability of the northern study site and its surrounds, for exploiting the eel migrations during autumn. The weirs enable resource surplus; the modification and use of these trees is the means to preserve this seasonally abundant and nutritionally rich resource; and the culturally modified wetlands with their perennial staple foods makes it possible for a sedentary occupancy of this area. There are sufficient sinkholes and wetlands to guarantee daily availability of live specimens but it appears that the north area is highly suited to trapping and preserving eels. The quality and fat content of the eel during the migration season (Sumner and Hopkirk 1976; Sumner et al. 1984; Fankhauser 2001) makes the investment of energy in the trap construction, tree and channel modification worthwhile. This utilisation of this resource supports the claim for a resource specialisation which incorporates its preservation, storage and/or trading.

Ethnographic and archaeological research (Godfrey 1994) informs us that Gunditjmara visited the coast for the summer months. From the evidence it can be assumed that for the other three seasons, at least, certain clans would have occupied the stony rises of the Mt Eccles lava flow, managing the wetlands previously created by their ancestors, spearing or trapping eels, smoking, preserving and storing them for trade, later consumption by families, or by the large organised gatherings (Lourandos 1980a & b,1983, 1985, 1987, 1991,1997).

The nature of British colonisation and the huge loss of Indigenous numbers masked the extent of previous Gunditjmara landuse patterns and the resulting socio-economies. This occurred despite various ethnohistorical reports alluding to an economy based on the ownership of eel weirs and associated villages (Dawson 1881; Clark 1998). It was not in the squatter's interests to record the high population numbers or any Indigenous infrastructure. The squatters were initially unlawfully residing, and they had good reason to downplay the nature of Aboriginal occupation. The draining of the wetlands and lakes has disguised the landscape from its previous incarnation. The European perspective of their use of this landscape is summarised thus:

> The main theme of the history is the transformation of the Shire from forest, swamps and stones to highly productive pasture. The heroes of the story are the successive waves of squatters, selectors and soldier settlers who have accomplished this transformation...(Yule 1988:viii).

The irony is that under Gunditjmara management the Mt Eccles lava flow was far more productive in the numbers of people that it could sustain than those sustained under the subsequent European grazing regime.

When the eel traps and CMTs are investigated in combination, it is evident that the two form a nexus to efficiently exploit migrating eels. It demonstrates that the focus of Gunditjmara socio-economy is not merely built around the daily provision of food – which can be obtained from the growing ponds or culturally modified wetlands. This economy was based on wetland management specialising in the production of surplus resource and its preservation. Its physical manifestation can be read in the landscape of the Mt Eccles lava flow. The spatial relationships and economic nexus between wetlands, dwellings, channels and weirs remain as material evidence of a former Indigenous economy based on permanence and sustainability. Their system had socio-economic implications (Builth in press).

CONCLUSION

All of the above observations and its interpretation support the landscape as being the product of a sophisticated management regime. Indigenous people occupying the landscape of the Mount Eccles lava flow at the time of European contact had achieved sustainable development by adapting appropriate extractive technology to an enhanced local ecology. Subsequent European land-use focused on draining the area and establishing grazing regimes.

The potential of the Mt Eccles landscape to sustain the incumbent Aboriginal society based on its ecological potential and its anthropogenic utilisation has been investigated and supported by archaeological research. The question of whether the utilisation was seasonal or perennial can be ascertained by examining landscape productivity. The potential of the environmental management of the Mt Eccles lava flow coupled with the ecological traits of the shortfin eel means that it is feasible to have sedentary settlement on this landform. Human occupation patterns respond to resource availability.

The extent of Gunditjmara transformation of the landscape in order to exploit the shortfin eel has all the characteristics of it having been domesticated (Erickson 2000). The archaeology has revealed evidence of a landscape-scale fishery present throughout the entire southern portion of the landform – covering at least 100sq kms. It is argued that the "natural environment", existing at the time of European arrival, was an anthropogenic product reflecting human ingenuity. It had been created, maintained and managed by a collective multigenerational knowledge, and involved a cooperative, governed society (Builth in press). A mosaic of wetlands, stony rises and woodland had been integrated by environmental opportunism and technology to serve the socio-economic interests of Gunditjmara.

The cultural construction of an extensive aquaculture and processing system, with the built-in means to ensure its seasonal sustainability and perennial occupation, demonstrates technology hitherto unrecognised in Australian Aboriginal societies. The chronology associated with the development of the aquaculture system is presently under investigation. Further research is necessary to identify any relationship between palaeoenvironmental responses to climate change and possible Gunditjmara intervention. Ramifications of such anthropogenic activity may or may not have had social implications leading to the development of social complexity as outlined by Lourandos (1980a & b,1983, 1985, 1987, 1991,1997).

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